AD-763 139

THE FAR INFRARED AND SUBMILLIMETER BACKGROUND

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Ithaca, New York

1 September 1972

AFCRL - 72 - 0616

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Contract No. F19628-70-C-0128

Project No. 8692

FIRST DATA REPORT
On Flight 3

1 September 1972

Contract Monitor: Stephan D. Price
Optical Physics Laboratory

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Defense Advanced Research Projects Agency
ARPA Order No. 1366

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ARPA Order No. 1366
Program Code No. OE50
Contractor: University of Rochester
Effective Date of Contract: 6 November 1969

Contract No. F19628-70-C-0128
Principal Investigator and Phone No.
Dr. Martin O. Harwit/607 256-4805
AFCRL Project Scientist and Phone No.
Stephan D. Price/617 861-2501
Contract Expiration Date: 30 June 1973

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TECHNICAL REPORT (TR) No: AFCRL-TR-72-0616

TITLE: The Far Infrared and Submillimeter Background

a. LETTER OF TRANSMITTAL/CERTIFICATION. (AFR 80-45 & AFSC Sup 1)

(X) None.
( ) Improper/insufficient.

b. DISTRIBUTION STATEMENT. (AFR 80-45 and AFSC Sup 1 thereto).

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( ) None.
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Block Numbers ______ not completed.
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d. TR NUMBER. (Paragraph 5.2.1 1, MIL-STD 847A).

( ) None.
( ) Incorrect.

e. IMPROPER STATEMENTS. (Paragraph 5.2 or 5.3 MIL STD 847A)

( ) Cover.
( ) Title Page.
( ) DD Form 1473
( ) Other.

f. REFERENCES TO CLASSIFIED COMMENTS. (Paragraph 5b, AFSCR 80-20).

( ) Reference List or Bibliography.
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Paragraph and Page Number ______

g. OTHER:

( ) ______

( ) ______

h. COMMENTS:

5/25 - Called Mr. Lobo

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AD 763139

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*

Cornell University
Center for Radiophysics and Space Research
Ithaca, New York 14850

2a. REPORT SECURITY CLASSIFICATION

Unclassified

2b. GROUP

3. REPORT TITLE

THE FAR INFRARED AND SUBMILLIMETER BACKGROUND

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Scientific. Interim.

5. AUTHOR(S) *(First name, middle initial, last name)*

James R. Houck
Judith L. Pipher
Baruch T. Soifer
Martin O. Harwit

6. REPORT DATE

1 September 1972

7a. TOTAL NO. OF PAGES

~~15~~ 20

7b. NO. OF REFS

18

8a. CONTRACT OR GRANT NO. ARPA Order No. 1366

F19628-70-C-0128

b. PROJECT, TASK, WORK UNIT NOS.

8692 n/a n/a

c. DOD ELEMENT 62301D

d. DOD SUBELEMENT n/a

9a. ORIGINATOR'S REPORT NUMBER(S)

First Data Report on Flight 3

9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

AFCRL-72-0616

10. DISTRIBUTION STATEMENT

A - Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES

This research was supported by the Defense Advanced Research Projects Agency.

12. SPONSORING MILITARY ACTIVITY

Air Force Cambridge Research Laboratories (OP)
L. G. Hanscom Field
Bedford, Massachusetts 01730

13. ABSTRACT

We have repeat~~ed our~~ earlier observations of the infrared and submillimeter background radiation. While the measured values of the infrared background radiation remain unchanged, we have failed to observe the high flux previously reported for the 0.4 to 1.3 mm range. This indicates that the flux cannot have been galactic or cosmic, but further observations are needed to rule out a solar cycle dependent geocoronal origin.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Infra-red						
Submillimeter						
Background						

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ABSTRACT

We have repeated our earlier observations of the infrared and submillimeter background radiation. While the measured values of the infrared background radiation remain unchanged, we have failed to observe the high flux previously reported for the 0.4 to 1.3 mm range. This indicates that the flux cannot have been galactic or cosmic, but further observations are needed to rule out a solar cycle dependent geocoronal origin.

An Aerobee 170 rocket was launched on flight KP 3.40 at 00:21 Mountain Standard time on July 18, 1972. At an altitude of 144 km above White Sands, New Mexico the nose cone was ejected, and a liquid helium cooled telescope similar to one flown previously, started observing the sky in six wavelength bands 5-6, 12-14, 16-23, 85-115, 200-300, and 400-1300μ.

In this letter we report the background radiation observed, and make a comparison with previous results. Earlier data reported by our group (Shivanandan et al., 1968, Houck and Harwit, 1969, Pipher et al. 1971) had set upper limits on a uniform background and had presented evidence for a relatively high background level at submillimeter wavelengths.

The submillimeter flux appeared isotropic and hence could not be attributed to simple atmospheric emission. If galactic or extragalactic in origin, the flux was barely consistent with X-ray background observations, (Hudson, et al., 1971) provided the X-radiation was produced by inverse Compton scattering of energetic electrons in the Galaxy. In addition restrictions on the spectral shape of an interstellar or extragalactic submillimeter flux were placed (Bortolet et al., 1969, Hegyi et al., 1972) by the low excitation states observed in interstellar atoms and by high spectral resolution mountain top (Mather et al., 1971, Nolt et al., 1972) and aircraft (Beckman et al., 1972) observations which detected only radiation that could be attributed to atmospheric emission. Other direct

observations from rockets reported by the Los Alamos group indicated that the submillimeter flux would have to be at wavelengths less than 0.8 mm. Moreover, recent balloon observations by Muehlner and Weiss (1972) suggested that all their detected flux could be attributed to atmospheric emission.

In an attempt to settle such discrepancies, we have made a further measurement of the submillimeter background, but have failed to observe the earlier high signals.

In this flight instrumental changes were made to eliminate a number of possible sources of signal contamination. Several of these sources of contamination have been discussed previously (Shivanandan et al., 1968, Houck and Harwit 1969b). Others were suggested to us by many colleagues.

1) Earth shine diffracted into the telescope at its open end;

2) Direct thermal radiation from the horizon which is multiply reflected inside the telescope;

3) The slow decay of oxygen atoms swept up as the rocket traverses the upper atmosphere. (These atoms can be trapped on cryogenically cooled surfaces, and atomic beam studies indicate that de-excitation of the electronic excited states occurs over times of the order of at least many minutes.) We are grateful to Dr. D. Offermann from Bonn for bringing this effect to our attention;

4) Radiofrequency interference in the payload.

While calculations and experimental evidence argued against significant contributions by these effects, we nevertheless modified our liquid helium cooled telescope to be less sensitive to these types of interference. We did this by passing the observed radiation through additional field and aperture stops. A drawing of the optical system is shown in Figure 1.

We also minimized radio frequency interference by the use of additional shielding, changes in electronic circuitry, and elimination of both telemetry and radar tracking during a portion of the flight. During the entire flight including the 30 second period of interrupted telemetry and radar tracking all signals were recorded by an onboard tape recorder.

The tape record indicates that radio frequency and radar interference were not present on this flight. The data, however, also fail to reproduce the previously reported high submillimeter signals.

Our upper limit now is several times lower than the previously reported flux. The currently measured flux is slightly negative with respect to the $4.2^{\circ}K$ telescope temperature before the nose cone and telescope cover are ejected, at altitude. Its relative value is $-2 \times 10^{-10} \pm 2 \times 10^{-10}$ watt cm^{-2} sr^{-1}. The signal expected from a $4.2^{\circ}K$ telescope would be 3.6×10^{-10} watt cm^{-2} sr^{-1}. The actually observed signal coming from above the telescope therefore amounts to $1.6 \times 10^{-10} \pm 2 \times 10^{-10}$ watt cm^{-2} sr^{-1}. In the wavelength range between 0.4 and 1.3 mm,

where our detector is sensitive, the expected flux from a 2.7°K black background would be 0.4×10^{-10} watt cm^{-2} sr^{-1}. These levels are shown in Figure 2 and Table 1 which also give background radiation levels observed on this and previous Cornell University flights, and present the most recent data reported by other observers.

It is possible that improved stray radiation rejection could have eliminated the combined effects of the contamination sources 1, 2, and 3, listed above. In addition, effect 3 by itself should have been reduced by a factor of order three, since the telescope was opened at an altitude ranging from 25 to 36 km higher than on previous flights. A separate rocket flight would be required to isolate each of these sources of contamination.

While the many improvements in the apparatus would lead us to believe that the present observations, are, if anything, more reliable than those carried out in the past, it is worth noting that the detector field of view has substantially decreased with subsequent flights. At the present time, the focal plane aperture defining the field of view is only twice the diffraction limited size at the longest wavelengths in the acceptance band. Because our calibrations are most sensitive at the shortest wavelengths in the acceptance band, some small losses in efficiency in the actual background measurement are possible at the longest wavelenghts. This effect is countered

to some degree by an inverted cone feed to the detector, which acts as an efficient integrating cavity, particularly at the longest wavelengths. That our results are not substantially affected by diffraction losses is borne out by the following consideration: the field of view on the 1970 flight (Pipher et al., 1971) was only twice the present value, while on the earliest flights it was ~ 13 times larger. The 1970 result, while lower than the 1968-9 results by a factor of two, was certainly much larger than the present result although the aperture sizes are comparable.

It is also important to realize that a geocoronal effect cannot be ruled out by our current observations. The earliest measurements were taken at solar maximum, while all the more recent observations have been taken nearer minimum solar activity. We know of no specific mechanism which could be responsible for a geocoronal effect, but it is interesting that the Lyman-α geocorona has a flux of the order considered here, is only mildly anisotropic compared to limits that could be set with our instrumentation, and varies in brightness as a function of solar cycle.

While the present low submillimeter background observations are inconsistent with earlier flights, background measurements at other wavelengths are in good agreement with earlier data. The minimum signal observed at 100 microns is consistent with earlier values obtained by our group and by Los Alamos and NRL.

In earlier papers, (Harwit, Houck and Wagoner, 1970; Pipher, _et al_., 1971) we had pointed out that submillimeter background radiation flux levels give limitations on the amount of energy emitted by typical galaxies during past epochs.

The lower submillimeter signals now reported give even more stringent limitations, and indicate that the universe cannot have converted an appreciable fraction of mass into electromagnetic energy -- no more, at least, than fractions of the mass now visible in the form of galaxies. These results are shown in Table 1.

On our present flight, Jupiter was detected twice in each of the four shortest wavelength bands. This has permitted us to recalibrate our flight instrument in terms of observations obtained by other observers, and gives us a calibration of background fluxes independent of our own laboratory blackbody calibrations. We find excellent agreement, using these two techniques. The principal uncertainties at 20μ and 100μ are in the quoted brightness of Jupiter in these wavelength bands. Since our earlier flights were carried out using the same blackbody technique, a satisfactory cross-calibration relative to other infrared astronomical standards seems to have been established in this way (Aumann _et al_., 1969, Gillett _et al_., 1969 and Low, 1966).

We are grateful to R. Nidey and T. Avery of KPNO for their care and dedication to the project, and we thank G. Stasavage in our laboratory for excellent technical support.

TABLE 1

Wavelength	Flux (10^{-11} Watt $cm^{-2} sr^{-1}$)	Z	$\Delta\epsilon/\rho_o c^2$	Source
5-6 μ	3	-----	%	Soifer et al., 1971
12-14	6	-----		Soifer et al., 1971
16-23	13	-----		Soifer et al., 1971
85-115	≤6	0.2-0.7	0.1	present data
130-200	<240	0.9- 2	9	Blair et al., 1971
200-450	8	2-5.5	0.6	Pipher et al., 1971
400-1300	<15*	5-17	3	Muehlner and Weiss, 19
400-1300	12±20	5-17	2	present data
800-1200	<2*	10-16	0.4	Muehlner and Weiss, 19
1200-1800	3			Muehlner and Weiss, 19
800-6000	<15			Blair et al., 1971

*Corrected for atmospheric emission

Upper limits and measured values of infrared and submillimeter background radiation. A the three shortest wavelengths, the minimum observed flux may be due to zodiacal dust emission. The third column represents the wavelength shift required to bring a cosmic source emitting at 70μ, into the spectral range measured. The fourth column gives the maximum fractional mass that could have been converted into radiation at 70μ, by galaxi during past epochs, without exceeding the observed flux. (cf. Harwit, Houck and Wagore 1970). The wavelength at which the emission of many infrared objects appears to peak i ~ 70μ.

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Figure Captions

Figure 1. Optical system used on present flight.

Figure 2. Comparison of the Flux from a 2.7°K Blackbody with the Results of Various Experiments. Sources of the direct measurements are identified in Table 1. Interstellar molecular data are due to the NASA group (cf. Bortolet *et al.*, 1969), and Hegyi *et al.*

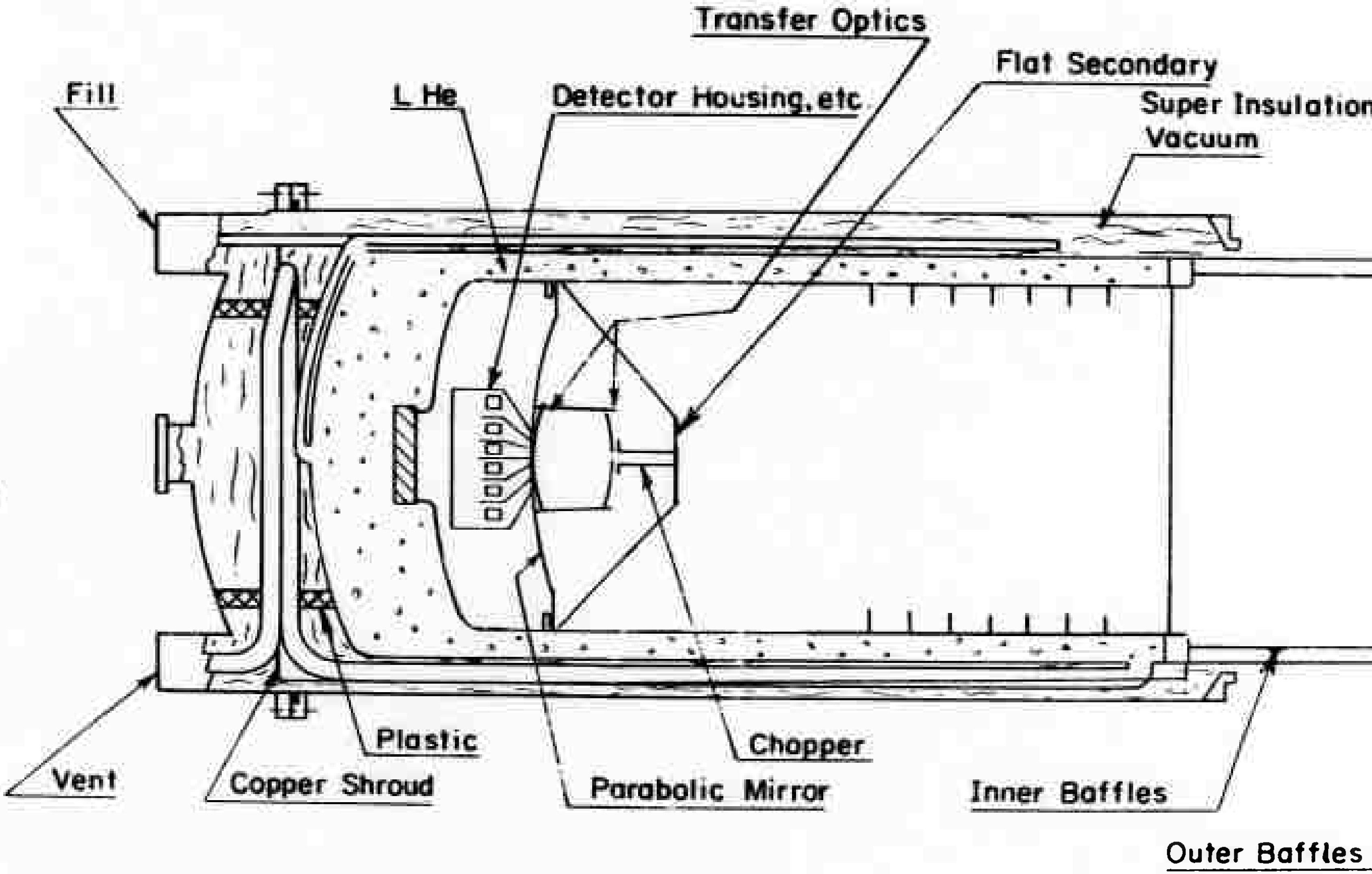

Transfer Optics
Flat Secondary
Fill
L He
Detector Housing, etc
Super Insulation
Vacuum
Plastic
Chopper
Vent
Copper Shroud
Parabolic Mirror
Inner Baffles
Outer Baffles

Figure 1.

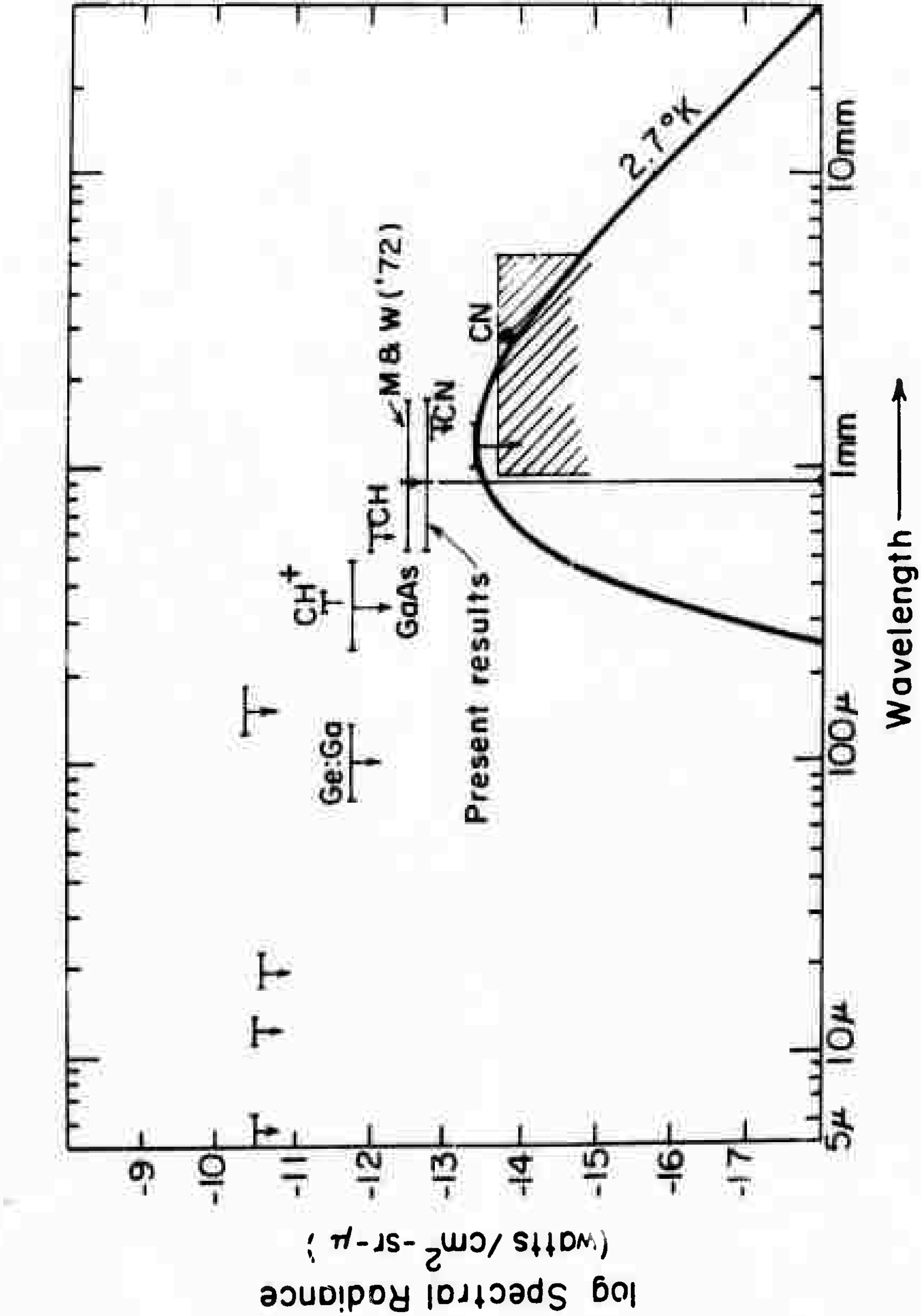
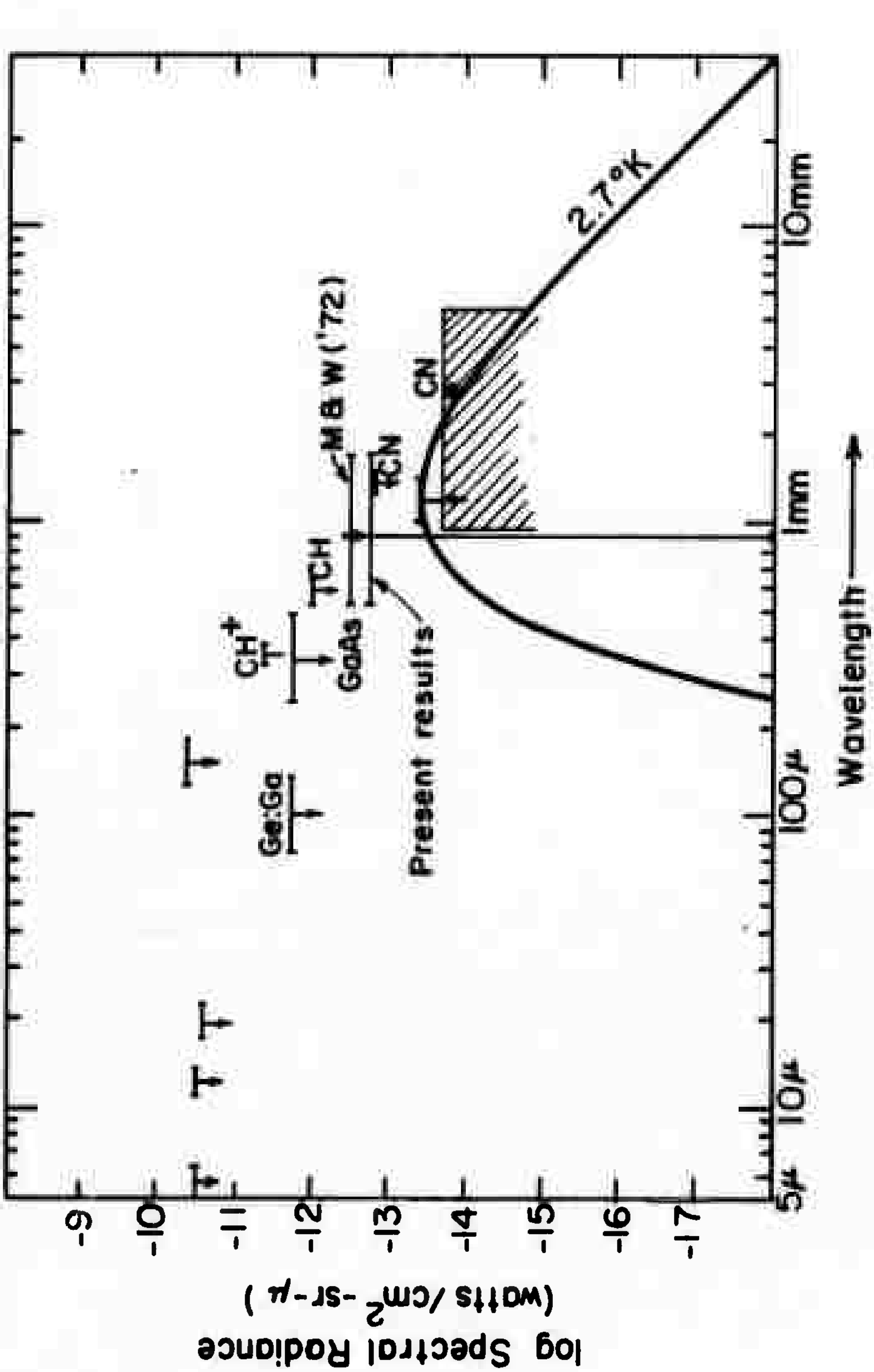
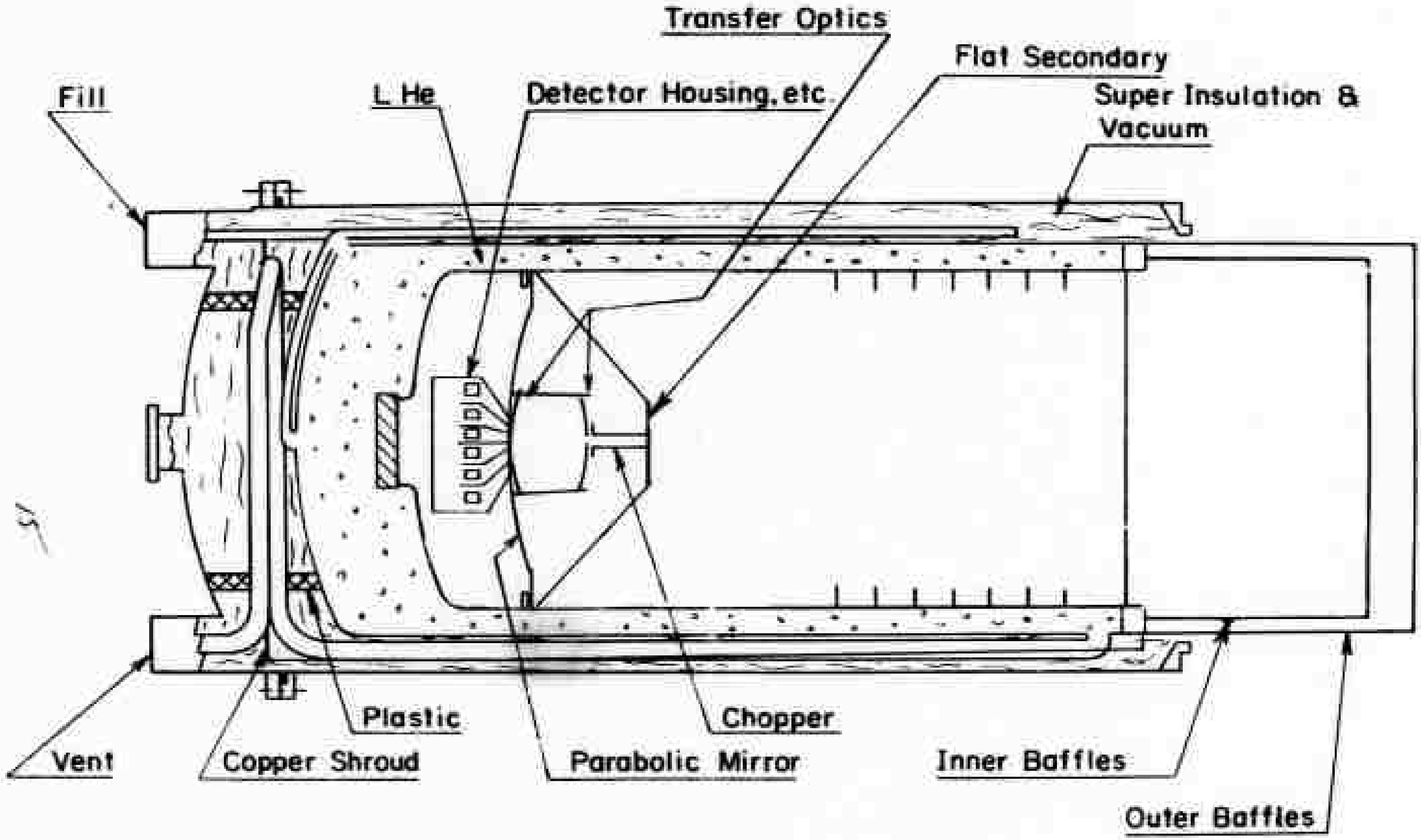

log Spectral Radiance
(watts/cm^2-sr-μ)
-9
-10
-11
-12
-13
-14
-15
-16
-17
5μ
10μ
100μ
1mm
10mm
Wavelength
2.7°K
Ge:Ga
CH$^+$
GaAs
CH
CN
CN
M & W ('72)
Present results

Figure 2.


log Spectral Radiance
(watts /cm^2 -sr-μ)
-9
-10
-11
-12
-13
-14
-15
-16
-17
5μ
10μ
100μ
1mm
10mm
Wavelength →
2.7°K
M & W ('72)
CN
CN
CH
CH$^+$
GaAs
Ge:Ga
Present results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Super Insulation &
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Plastic
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